Patent Claims

1. Low temperature extrusion process for energy optimized, viscosity adapted micro-structuring of frozen aerated masses like ice cream with over the length of the extruder screw channel zone-wise adapted mechanical treatment of the partially frozen, aerated mass with respect to its local viscosity, carried out such that, in each of the subsequent zones proceeding dispersing of air bubbles/air cells and at the same time temperature decrease and related increase of the frozen water fraction is achieved.

2. Process according to claim 1 characterized by a characteristic length of the zones into which the extruder is divided with respect to the adaptation of the mechanical energy input for ongoing dispersing of air bubbles/air cells and synchronously decreasing temperature or increase of frozen water fraction respectively, being the one to tenfold of the outer screw diameter, preferably the one to twofold of the outer screw diameter.

3. Process according to claim 1 characterized by a characteristic length of the zones into which the extruder is divided with respect to the adaptation of the mechanical energy input for ongoing dispersing of air bubbles/air cells and synchronously decreasing temperature or increase of frozen water fraction respectively, being the one to tenfold

of the outer screw diameter, preferably the one to twofold of the outer screw diameter with constant length of these zones along the extruder.

4. Process according to claim 1 characterized by a characteristic length of the zones into which the extruder is divided with respect to the adaptation of the mechanical energy input for ongoing dispersing of air bubbles/air cells and synchronously decreasing temperature or increase of frozen water fraction respectively, being the one to tenfold of the outer screw diameter, preferably the one to twofold of the outer screw diameter with characteristic zone length adapted to the local change of the mass viscosity.

5. Process according to claim 1 characterized by an adaptation of the processing parameters rotational screw speed (1), mass flow rate adjusted by a positive replacement pump installed at the extruder inlet (2) and cooling temperature at the inner wall of the extruder housing adjusted by the evaporation pressure of the refrigerant used (3) for given extruder screw geometry, regulated in such a way, that for conventional standard vanilla ice cream mass temperature ≤–11° C or more generally a frozen water mass fractions of ca. ≥60% related to the total freezable water fraction are achieved within the first 50 – 75% of the length of the extruder measured from the extruder inlet, preferably within 50 – 65% of the length.

6. Process according to claims 1 to 5 characterized by an adjustment of the mechanical mass treatment with respect to its viscosity in the related extruder zone by adapted variation of the screw channel height.

7. Process according to claims 1 – 5 characterized by an adjustment of the mechanical mass treatment with respect to its viscosity in the related extruder zone by adapted variation of the number of screws.

8. Process according to claims 1 – 5 characterized by an adjustment of the mechanical mass treatment with respect to its viscosity in the related extruder zone by adapted variation of the screw angle.

9. Process according to claims 1 – 5 characterized by an adjustment of the mechanical mass treatment according to its viscosity in the related extruder zone by adapted width variation of cuts in the screw flight(s).

10. Process according to claims 1 – 5 characterized by an adjustment of the mechanical mass treatment with respect to mass viscosity in the related extruder zone by adjusted pins fixed at the inner extruder barrel wall in such a way that they intermesh with the cuts in the screw flights.

11. Process according to claims 1 – 5 characterized by an increasing temperature reduction and increasing frozen water fraction along the

extruder length due to optimized heat transfer to an evaporating refrigerant contacting the outer wall of the extruder housing by minimizing the leakage gap width between the outer screw flight diameter and the inner extrusion housing diameter.

12. Process according to claims 1 – 5 characterized by a decreasing mass temperature, related increasing frozen mass fraction and increasing dispersing of the microstructure along the extruder length due to optimized heat transfer to an evaporating refrigerant contacting the outer wall of the extruder housing by generating a flow pattern at the outer front end of the screw flight, which leads to a reduction of the frozen material wall layer thickness not being wiped off by the screw flight(s) smaller than the leakage gap width.

13. Process according to claims 1 – 5 characterized by a decreasing mass temperature, related increasing frozen mass fraction and increasing dispersing of the microstructure along the extruder length due to optimized heat transfer to an evaporating refrigerant contacting the outer wall of the extruder housing by generating a flow pattern at the outer front end of the screw flight, which leads to a reduction of the frozen material wall layer thickness not being wiped off by the screw flight(s) smaller than the leakage gap width by adjusting the profile of the screw flight front edge which is inclined to the inner barrel wall or rounded with a well defined radius.

14. Device for low temperature extrusion under energy optimized viscosity adapted micro-structuring conditions of frozen aerated systems like ice cream according to claim 1 or one of the subsequent claims with variable screw geometry along the extruder length locally adjusted according to the local viscosity with respect to efficient progressive dispersing, simultaneous progressive temperature reduction and related freezing of water.

15. Device according to claim 14 characterized by a leakage gap width between screw flight and inner wall of the barrel of less than 0.1 mm preferably less than 0.05 mm.

16. Device according to claim 14 characterized by a screw flight thickness between 2 and 20 mm and 1.: screw flight front edge inclination relative to the inner barrel wall of 10-45°, preferably 30 – 35°, the inclination preferably applied to the outer first 2 mm of the screw flight height, **or** 2.: rounded screw flight front edge with a radius of preferably ≥2 mm.

17. Device according to claim 14 characterized by an extruder screw channel height adjusted along the extruder length to mass viscosity whereas in the feeding zone (I) of the extruder the ratio of the screw channel height H to the outer screw diameter D is preferably adjusted between 0.03 and 0.07, in the middle (length) zone (II) between 0.1 and 0.15 and in the final third of the extruder length between 0.1 and 0.25.

18. Device according to claim 14 characterized by a continuously increasing screw channel height over the extruder length such that the unscrewed contour line of the screw root between mass inlet and outlet, with the centre length axes of the screw forms an angle of 0.03 to 0.1 °, preferably 0.05 to 0.07 °.

19. Device according to claim 14 characterized by screw(s) comprising 3 to 7 preferably 4-5 screw flights in the first third of the extruder length; with 1-4, preferably 2-3 screw flights in the second third of the extruder length and with 2-3 preferably 1-2 screw flights in the final third of the extruder length in the vicinity of the extruder outlet.

20. Device according to claims 14 and 19 characterized by a progressive reduction of the number of screw flights over 2-10 preferably 3-5 equal or variable length segments of the extruder, whereas the number of screws is continuously reduced by 1-2 screw flights from segment to segment.

21. Device according to claim 14 characterized by screw angles in the inlet zone (I) between 35 and 90°, preferably between 45 and 60°, in the middle of the extruder between 30 and 45°, preferably between 30 and 35° and in the final third of the extruder length between 20 and 35° preferably between 25 and 30°.

22. Device according to claim 14 characterized by a constant or variable screw angle reduction between 45 and 90°, preferably 45 and 60° from the extruder inlet zone (I) - to - between 20 to 35° preferably 25 to 30° in the extruder outlet zone (III).

23. Device according to claim 14 characterized by cuts in the screw flights over the first 10 to 30%, preferably 15 to 20% of the extruder length.

24. Device according to claims 14 and 21 to 23 characterized by screws having more than one screw flight and cuts in the respective screw flights which are shifted axially such that the mass is subjected to scraping/"wiping off" flow at each part of the inner barrel wall.

25. Device according to claims 14 and 23 characterized by cuts in the screw flights where the length of these cuts is the 2.5- to 3-fold, preferably the 1- to 2-fold of the screw channel height and where the same dimensions are valid for the non-cut parts of the screw flights.

26. Device according to claims 14, 23 and 24 characterized by inbuilt elements, e.g. pins, connected to the inner barrel wall, intermeshing with the cuts in the screw flights during screw rotation.

27. Device according to claims 14 and 25 characterized by elements, e.g. pins, connected to the inner barrel wall at 2-10, preferably 3-5

different positions regularly or irregularly arranged at the perimeter of the inner barrel wall.

28. Device according to claims 14 and 25 to 27 characterized by more than one screw flights where cuts in these screw flights have the same axial position to allow for intermeshing with the inbuilt elements, e.g. pins.

29. Device according to claims 14 and 28 characterized by a single or twin-screw extruder arrangement for low temperature extrusion of frozen, aerated masses and adapted geometry characteristics according to one or more of the claims 14 to 28.